7TH INTERN. CONGRESS OF SOIL SCIENCE, MADISON, WISC., U.S.A., 1960 V.21

STUDIES ON QUANTITATIVE RELATIONSHIPS BETWEEN SOILS AND SOIL-FORMING FACTORS IN NORWEGIAN FORESTS

by

J. LÅG

Agric. College of Norway, Vollebekk, Norway.

Considering the historical development of the different sciences we find as a general feature a steadily increasing use of numerical characterizations of the properties or processes studied. The development from stages of description to stages of induction of quantitative laws is well known for many natural science subjects. Lord Kelvin's words about being able to measure what one is talking about, may serve as a motto for the growth of most natural sciences.

Thus, in natural sciences and related subjects emphasis has been laid on measuring properties and processes that are directly measurable. Further, a great deal of work has been put into the development of systems of measurement for study objects that cannot be measured directly by any known methodics. Similar trends of development have been found in other subjects as well.

The development of soil science is similar to that of the socalled classical natural science subjects. However, the history of soil science is still comparatively young. The time during which the soil-forming factors have been fairly well established covers a little over 80 years. Leaving human influence out of account, we find that the factors determining the properties of the soil are as follows: 1) climate, 2) living organisms, 3) mineral material, 4) topography, and 5) time of soil formation. There are interrelationships between some of these groups of soil-forming factors, and to some extent mutual interaction between the factors and the soil.

One would think that great efforts would have been made to elucidate the effect of the different soil-forming factors. A great deal of work has indeed been done in this field, but the quantitative relationships known are relatively few so far.

There are several reasons for this. As stated above, the history of soil science is relatively young, compared with that of the classical natural sciences. During this period, however, an enormous numerical material has been presented in other parts of this subject. The problem in itself is very hard to approach, and this is probably the major reason why so little is elucidated yet. Considering the five soil-forming factors, we find that only time can be completely characterized by a single number. For some of the factors (or rather factor groups) it is very difficult to find quantitative expressions. Hoping that it will bring the elucidation of the effects of these factors a step forward, I have tried to make use of rank order scales (Låg 1958, 1959). For vegetation, rough groupings of plant communities can be used, and the mineral material can be classified according to mechanical composition, occurrence of different minerals, etc.

In Norway very wide variations are found within most groups of soil-forming factors. In several respects, therefore, the natural conditions should favour an elucidation of these questions.

In 1954, after a period of relatively comprehensive preparatory work, we began collecting a large material, which to some extent can be used to throw light on these problems. Some elementary registrations of soil conditions were started at that time, in connection with the investigations of Norwegian forests carried out by the National Forest Survey. Till now soil investigations have been carried out on about 60 000 sample plots. The sizes of these plots are 78 sq.m or 100 sq.m. All plots examined lie in productive forest. So far the investigations have been concluded for 7 of our 18 rural counties, but the material has not been calculated in its entirety as yet.

The notations made apply to profile type, mechanical composition, soil material classified according to its origin, depth of soil, gradient, tree species, ground cover vegetation and height above sea-level, etc. In addition there are of course a large number of registrations of conditions of special silvicultural interest, but these are of less importance for the problems dealt with in the present paper.

Podzol is the most common great soil group in the Norwegian forests. However, we have also some brown earth. In the areas where both of these two, essentially different main soil types occur, the approach to the question of the influence of the soil-forming factors should be relatively simple. Owing to small changes in the soil-forming factors the soil profile may here pass from one main type to another. In dealing with a numerical material as comprehensive as this one it seems possible to take out a large number of sample plots showing variation for one of the soil-forming factors, while the rest remain relatively constant. A displacement of the proportional area of brown earth to podzol has been used as a measure of the effect of the changes in the soil-forming factor. Hence the change in each individual factor leading to the same displacement in the proportional area of the soil types should have the same effect. In other words, it should be possible by this method to find the magnitude of the changes required for the different factors to balance each other. This working method may be said to have for its principle the quantitative expression of the effect of the different soil-forming factors on the basis of mutual counterbalancing of the changes in each individual factor.

It is of course difficult to find an initial material showing variations in only the one soil-forming factor which one disires to study. It is as a rule impossible to be quite certain that this condition has been fulfilled. We may, therefore, often have to be content using a material in which variation can be established in one factor, or factor group, only.

In dealing with the Norwegian numerical material it has been sought to divide it into areas with approximately the same type of bedrock and type of climate. Morainic deposits constitute the predominant soil material, and the sample plots on these have chiefly been used in the subsequent calculations. Special groupings have been made according to coarse sand and fine sand. Further, the sample plots have been grouped by vegetation (tree species and ground cover vegetation), gradient and height above sea-level. Thus, within districts with about the same bedrock and type of climate, the sample plots can be gathered in groups with approximately the same mechanical composition, vegetation, gradient, and height above sea-level. Where brown earth and podzol occur it is possible to study how a change in one single of these factors, leads to a displacement in the proportional area (frequency of sample plots) of the two soils.

Correspondingly, comparisons of different districts may for instance bring out the influence of different rocks and of different types of climate.

By comparing the changes in the proportional area of the soil types due to the individual factors, it should thus be possible to evaluate on a quantitative basis the different soil-forming factors. When dealing with factors for which there are only scales of rank order, it will be necessary to compare the 'distances' on these scales, and also the 'distances' and the quantitative characterizing of the other factors (e.g. the 'difference' between pine and spruce, or between the different rock material, compared with the differences in gradient).

It is therefore necessary to have a very large initial material to be able to carry out comparisons of this type. Modern technique, making use of punch cards for calculation, facilitates this work. However, this kind of calculation is expensive and sufficient grants for carrying out the comparisons that might be considered desirable are not easily obtained. Even with an increase in material averaging 10 000 sample plots a year, it will take a long time before the material is sufficiently large to enable the carrying out of a number of the grouping desired.

A few examples of the preliminary results obtained in the comparisons carried out so far, are mentioned below.

A discussion has been going on for a long time concerning the influence of the different tree species on the development of the soil profile. In silviculture it is in some cases a question of changing from one tree species to another. Thus, in dealing with the problem of the effect of the tree species on the soil, we are faced with problems of great economic consequences.

Concerning the soil formation in the forest, however, the ground cover vegetation also is of importance. As for the tree species a rank order scale can be used for the ground cover vegetation. (Due attention should of course be paid to the fact that tree species and ground cover vegetation in some measure are interdependent). A rough grouping used in Norway will serve as an illustration:

1. Forest ground rich in grasses and herbs;
2. Forest ground rich in mosses with some herbs;
3. Forest ground rich in *Vaccinium myrtillus* with *Dryopteris*;
4. Forest ground rich in *Vaccinium myrtillus* without *Dryopteris*;
5. Forest ground rich in *Vaccinium vitis-idaea*;
6. Forest ground rich in *Calluna vulgaris*;
7. Forest ground rich in lichens.

In a comprehensive numerical material it is possible to some extent to compare the relationship between the development of the profile under different tree species with the same ground cover vegetation with the relationship between the development of the profile under the same tree species with different ground cover vegetation, respectively.

The comparisons that have been made show the relationship between ground cover vegetation and development of profile to be closer than that between tree species and development of profile. In other words, there is a greater variation in the proportional area of podzol and brown earth on the scale for ground cover vegetation than on that for tree species (Låg 1959).

Elevation and gradient may be taken as examples of the effect of changes in measurable properties.

It is well known that in broad outline a correlation exists between temperature and height above sea-level. In many places the precipitation also increases somewhat with increasing height. Hence the relationship between the humidity of the climate and height above sea-level will be relatively close. The gradient is a very important character in topography.

Other conditions being equal, the area of brown earth in relation to that of podzol will therefore on the whole decrease with increasing elevation, and increase with increasing gradient. In the numerical material from the Norwegian forests the gradient has been divided into classes as follows: 0–10 %; 10–20 %; 20–33 %; and > 33 %.

A division into zones of 150 m has been made according to height above sea-level (0–150 metres, 150–300 metres, etc).

From the preliminary comparisons on the above-mentioned principles an increase in height above sea-level of 150 m seems in southern and eastern Norway to be approximately counterbalanced by an increase in gradient of one class.

The direction in the research aiming at providing quantitative expressions of the effect of the individual soil-forming factors, might possibly be termed soligenesimetry*). To solve problems of this type has been proved to be difficult. However, this should not prevent our trying to make also this part of soil science more exact.

REFERENCES

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SUMMARY

The principles of the elucidation of quantitative relationships between soils and soil-forming factors have been discussed. As a name for this direction in research soligenesimetry has been suggested.

In Norwegian forests attempts have been made to study the effect of the individual factors on the proportional areas of podzol and brown earth, respectively. The change in each individual factor leading to the same displacement in the proportional area of the soil types, should thus have the same effect. In other words, we should try to find the magnitude of the changes required for the different factors to balance each other. This working method may be said to have for its principle the quantitative expression of the effect of the soil-forming factors on the basis of mutual counterbalancing of the changes in each individual factor. For the factors that cannot be characterized numerically, the use of scales of rank order is suggested.

The development of the profile seems to be more intimately bound up with the type of ground cover vegetation than with the tree species. The podzol area increases with increasing height above sea level and decreases with increasing gradient. In the preliminary investigations referred to an increase in gradient from one class to the next seems to be approximately counterbalanced by an increase in height above sea level of one class (150 m).

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* New word, after consultation with Dr. Leiv Amundsen, Professor of Classical Philology at the University of Oslo.

RÉSUMÉ

Les principes qui doivent permettre d'élucider les relations quantitatives entre les sols et les facteurs qui les ont formés sont discutés. Le nom de soligénésimétrie est suggéré pour désigner ce genre de recherches.

Nous avons essayé d'étudier, dans les forêts de Norvège, l'effet des facteurs individuels sur la répartition proportionelle des surfaces couvertes par podsols et par sols bruns. Chaque variation de chaque facteur pris individuellement, qui aurait pour effet un même décalage dans la répartition proportionelle des surfaces, aurait donc un effet identique. En d'autres termes, nous devons rechercher quel ordre de grandeur les variations des divers facteurs doivent atteindre pour qu'ils puissent se compenser mutuellement. On peut dire de cette méthode de travail qu'elle a comme principe l'expression quantitative des effets des facteurs pédogénétiques basée sur la compensation mutuelle des variations de chaque facteur individuel. Pour les facteurs qui ne peuvent être chiffrés, l'auteur suggère l'utilisation d'échelles d'ordre de grandeur.

Le développement des profils semble être plus intimement lié au type de plante de couverture qu'aux espèces arborescentes. La surface proportionelle des podsols augmente avec l'altitude et diminue avec le degré de pente. Dans les recherches préliminaires reprises dans cette communication, une augmentation d'une classe de pente semble pouvoir être plus ou moins compensée par une augmentation d'une classe en altitude (150 m).

ZUSAMMENFASSUNG

Prinzipien für die Erörterung der quantitativen Beziehungen der Bodentypen zu bodenbildenden Faktoren werden besprochen. Als Benennung für diese Forschungsrichtung wird Soligenesimetrie vorgeschlagen.

In den norwegischen Wäldern hat man versucht den Effekt einzelner Faktoren auf die Arealverteilung des Podsols und der Braunerde zu studieren. Jede Veränderung jedes einzelnen Faktors, welche die gleiche Verschiebung der Arealproportion für diese beiden Bodentypen hervorruft, hätte demnach die gleiche Wirkung. Man sollte deshalb, mit anderen Worten ausgedrückt, für die verschiedenen Faktoren eine Grösse der Veränderung zu finden versuchen, die einander die Waage halten. Das Prinzip für diese Arbeitsweise kann veilleicht als der quantitative Ausdruck des Effektes der bodenbildenden Faktoren auf Grund der gegenseitig balancierten Veränderungen jedes einzelnen Faktors bezeichnet werden. Für Faktoren die nicht ziffermässig ausgedrückt werden können, wirden Rangskalen vorgeschlagen.

Die Profilentwicklung scheint mehr an die Bodenvegetation als an die angebaute Holzart gebunden zu sein. Das Areal des Podsols nimmt mit steigender Höhe über dem Meeresspiegel zu und nimmt mit zunehmendem Steigungsgrad ab. Bei diesen Untersuchungen wurde der Steigungsgrad in folgenden Klassen eingeteilt: 0—10 %, 10—20 %, 20—33 % und mehr als 33 %. Die vorläufigen Zusammenstellungen des Versuchsmateriales scheinen darauf hinzuweisen, dass ein Zunehmen des Steigungsgrades aus einer Klasse in die andere ungefähr dem Zunehmen von 150 m der Höhe über dem Meeresspiegel entspricht.

DISCUSSION

ODINSKY: What is the relation of elevation with respect to gradient?

J. LÅG: Any gradient class can be represented in every elevation class.